TITLE: Surgical management of impalement injuries to the trunk of dogs: a multicentre retrospective study

AUTHORS: M. Matiasovic Z. J. Halfacree A. Moores P. Nelissen S. Woods B. Dean G. Chanoit D. C. Barnes

JOURNAL: Journal of Small Animal Practice

PUBLISHER: Wiley

PUBLICATION DATE: March 2018

DOI: https://doi.org/10.1111/jsap.12767

Structured summary

Objectives: To review a large series of dogs referred for treatment of traumatic impalement injuries to the thorax and/or abdomen and to report the aetiologies, injury characteristics, management and long-term outcomes for these patients.

Methods: Retrospectively collected data of dogs surgically treated for impalement injuries to the trunk at six veterinary specialist referral institutions in the UK over an 11-year period were reviewed. Data collected were patient signalment, physiologic variables, injury-specific variables, diagnostic imaging reports, surgical procedures undertaken, duration of hospitalisation, antibiotic use, complications and outcomes. Data were reported with summary statistics.

Results: Fifty-four dogs were included. Impalement occurred most frequently on wooden objects (n=34) and the thoracic cavity was most commonly penetrated (n=37). Computed tomography was sensitive and specific to identifying wooden material in 64% and 88% of cases (n=11) respectively. Thoracotomy was performed in 56%, coeliotomy in 20% and a foreign body or its fragments were retrieved during surgery in 37% of the cases. Complications occurred in 19 dogs (35%) and of these 68% were minor and 32% major. The survival rate for thoracotomy cases was 93% (n=30). Overall long-term survival was 90%.

Statement: Despite the often dramatic presentation of impalement injuries the majority of patients treated in the specialist referral setting can achieve excellent outcomes. These injuries require thorough diagnostic imaging and interpretation

prior to adequate surgical exploration and management, augmented by anaesthetic and critical care during the peri- and post-operative periods; therefore stable patients should be referred to centres able to provide this type of care.

Keywords: canine, dogs, impalement, injury, trunk

Introduction

Penetrating injuries are a well-recognised cause of morbidity in dogs, however previous reports focus mainly on oropharyngeal foreign body penetrating injuries (White & Lane 1988; Griffiths *et al.* 2000; Doran *et al.* 2008), gunshot wounds and bite injuries from other animals (Risselada *et al.* 2008; Cabon *et al.* 2015). There is therefore a paucity of information in the veterinary literature evaluating penetrating injuries to the trunk in dogs caused by impalement on foreign bodies. Current reports are limited to three individual case reports (Pelosi *et al.* 2008; Menard & Schoeffler 2011; Appleby *et al.* 2015;) and a small case series evaluating seven dogs with thoracic impalement injuries (Zitz *et al.* 2007).

Impalement by definition is piercing or transfixation with a sharp instrument (Oxford English dictionary 2017). Some reports of impalement injuries in human medicine state the penetrating object responsible for the injury to be left protruding from, or attached to the victim (Morgan *et al.* 1988; Eachempati *et al.* 1999). An attempt has been made to classify impalement injuries into Type I (impact between the patient body and an immobile object) and Type II (intentional manipulation of a mobile object impacting a stationary patient) (Eachempati *et al.* 1999).

Impalement wounds affecting dogs most commonly involve the head, neck, or anterior thorax as the result of running onto a stationary pointed object (Type I) (Pavletic 2011). Impalement injuries can be deceiving as what initially appears to be a simple wound may actually conceal a more severe, even life-threatening internal injury, and therefore wound exploration limited only to the entrance point may underestimate the extent of the trauma (Pelosi *et al.* 2008; Menard & Schoeffler 2011). Cross-sectional imaging and use of a combination of modalities may be required to fully elucidate the extent of damage (Menard & Schoeffler 2011). Treatment recommendations are guided towards thorough surgical exploration and debridement of the full path of the impalement injury based on the entry wound and imaging findings (Zitz *et al.* 2007).

The purpose of this study was to review a large series of dogs that were referred for specialist treatment having suffered traumatic impalement injuries to the thorax and/or abdomen that were treated surgically and to report the aetiologies, extent of injuries, surgical management, long-term outcomes and complications encountered.

Materials and methods

This study was approved by the XXX

A cover letter calling for study participation was sent out to 17 UK veterinary referral centres. Subsequently, a data collection form (supplemented) was sent to participating institutions (n=6) and data were collected retrospectively from clinical records and diagnostic imaging reports at the respective institutions. Study inclusion criteria were as follows: impalement injuries to the trunk (thorax and/or abdomen) in dogs that required surgical treatment, with complete medical records available (initial history, clinical examination, diagnostic measures, surgical findings, aftercare until discharge and follow-up re-examination). Impalement injury was defined as a traumatic injury where the dog ran onto, or was directly traumatised by a linear object and that caused deep penetration of the skin, subcutaneous tissue +/- underlying body cavities. Impalement injuries that occurred via the oropharynx were excluded.

Data collected for each case were; patient signalment, mental status, physiologic variables, injury-specific variables, diagnostic imaging reports, procedure-related variables, duration of hospitalisation, antibiotic use, complications and long-term outcomes.

Complications were defined as minor (medically managed, requiring prolonged hospitalisation or self limiting but not requiring additional surgical treatment) or major (requiring additional surgical intervention, resulting in long-term loss of function, death or euthanasia) and were grouped as intraoperative, early postoperative (<14 days) and late postoperative (>14 days). Medium-term follow up was obtained by post-operative reassessment at the referral institution. Long-term follow up was obtained by telephone conversations with dog owners or referring veterinarians.

All data were reported with summary statistics. Normality was assessed by the D'Agostino & Pearson test and data were reported as mean (± SD) for normally distributed data and median (range or interquartile range (IQR)) for data not normally distributed.

RESULTS

Fifty-four cases were identified as meeting the inclusion criteria; they had presented to the participating institutions between January 2005 and January 2016. This cohort comprised 31 male (7 intact, 24 castrated) and 23 female (7 intact, 16 spayed) dogs. An average of 1.25 case per year were presented to an individual hospital participating in the study. Mean age was 48 (± 27) months with a median bodyweight of 25 (IQR 17-33) kg. Breed distribution was as follows: crossbreed (n=17), English springer spaniel (n=8), Labrador retriever (n=6), greyhound (n=3), Rhodesian ridgeback (n=3), whippet (n=3), border collie (n=2), English cocker spaniel (n=2), German shepherd (n=2), and one of each of the following: American bulldog, fox terrier, German wire-haired pointer, Jack Russell terrier, Neapolitan mastiff, rough collie, Staffordshire bullterrier and weimaraner.

Median time from injury to presentation at the referral institution was six hours (range 1 hour to 15 days) with the majority of cases presenting within 10 hours (n=36) but five cases (9%) presenting seven or more days after the initial injury. Six dogs underwent initial surgical intervention at the primary care practice to later (>24 hours) be referred due to complications a median of 5.5 (2 to 10) days following injury. All of these dogs underwent further surgical management.

Clinical presentation:

On presentation at the referral institution, mental status was normal in 27 dogs (50%), depressed in 23 dogs (43%) or stuporous in four dogs (7%). Fourteen dogs were non-ambulatory (26%) and 40 ambulatory (74%). The impaling object was still present *in situ* (penetrating into the wound) in 14 cases (26%) at presentation (Figure 1).

Impalement occurred most frequently on wooden objects (stick, tree branch, miscellaneous piece of wood) (n=34) (Figure 1), followed by unidentified objects (n=8), metallic objects (spikes (n=2), stakes (n=2), knives (n=2), gate post (n=1)) (totalling n=7) and deer antlers (n=4).

Penetration entry sites in total were as follows: 15 to the lateral thoracic wall (one case sustained injuries to both the left and right lateral thoracic wall), 14 to the ventral thoracic wall (below the level of the shoulder joint), 10 to the axilla, eight to the inguinal region, eight to the thoracic inlet, one cranial to the shoulder and one to the caudal ventral neck. Three of these cases had multiple penetration sites. These were caused in two cases by stag horn injuries (one to the right inguinal area and right thoracic wall and one to both sides of the thoracic wall) and in one case by an injury of unknown cause where the left thoracic wall and left inguinal area were penetrated. Cases grouped by site of injury are listed in Table 1.

Diagnostic imaging:

Diagnostic imaging performed to investigate the extent of injury prior to surgical exploration at the referral institution used a variety of modalities detailed in Tables 1 and 3 (Table 3 is supplementary data).

Data allowing review and comparison of intraoperative findings of wooden foreign material with preoperative imaging findings was available for 18 dogs.

In cases where wooden foreign material was present in the surgical site, this was preoperatively identified on computed tomography (CT) in 64% (7/11) and on radiography in 43% (3/7) of these cases. In one case a thoracic foreign body was suspected according to CT findings, however was not found on surgical exploration. Foreign wooden material was retrieved from the surgical site without being identified on diagnostic imaging (CT (n=1), CT + radiography (n=2), CT + radiography + ultrasound (n=1)) prior to surgery in 36% (4/11) of cases. Anatomical locations of penetration were different for these four cases and all of the wooden objects were wooden sticks. Sensitivity and specificity of CT to detect wooden objects was 64% and 88% respectively (data available for 11 cases).

Surgery:

Surgery was delayed for further cardio-vascular stabilisation of the patient by means of intravenous fluid resuscitation upon admission in 12 cases (22%). Blood products were administered perioperatively in five cases (9%).

Surgical wound exploration was performed in 51 cases (94%), in 14 it was the only procedure performed. One wound exploration was done endoscopically (axillary wound). Exploration revealed the thoracic cavity alone to be penetrated in 30 cases (56%) (Figure 1) and the abdominal cavity alone in five cases (9%). Both the thoracic and abdominal cavity were penetrated in seven cases (13%). Neither body cavity was penetrated in 12 of the cases (22%).

Thoracotomy was performed in 30 dogs (table 2). In one dog thoracoscopic exploration was performed in addition to an intercostal thoracotomy. Lung lobectomies were performed in 10 dogs, four of which developed postoperative complications (40%). Of these 10 dogs partial lung lobectomies were performed in five, an entire lung lobe was removed in four cases and more than one lung lobe was removed in one dog. Coeliotomy was performed in 11 cases. Two cases suffered liver lobe injuries; two penetration of the right ventricle of the heart and also two suffered intercostal artery lacerations. The following organs were injured additionally in one case each: urinary bladder, omentum, pericardium, stomach, small intestine, spleen and trachea. Injuries are detailed on a case-by-case basis in Table 3 (supplementary material).

A wooden foreign body or its fragments were retrieved during surgery in 20 cases (37%). Most of these were from dogs undergoing wound exploration with thoracotomy (n=8), followed by wound exploration alone (n=7), combined wound exploration / thoracotomy / coeliotomy (n=3), coeliotomy alone (n=1), and dorsal laminectomy (n=1). An additional approach to retrieve the foreign body (other than that for exploration) was required in six cases. This approach was made after following the wooden foreign body (n=3) or its tract (n=3) at their respective termination.

Seventy-five drains of various types were placed in 49 dogs and these were maintained for a median of 48 hours (range 6 hours to 10 days). Of these drains 36 were thoracic drains (all closed suction systems with intermittent drainage), 38 were wound drains (28 closed suction drains, 10 Penrose drains) and one was a closed suction abdominal drain. Two dogs required replacement of chest drains two and four days respectively after removal because of continued pleural effusion.

Median duration of anaesthesia was 190 (IQR 135 to 225) minutes and median duration of surgery was 105 (IQR 70 to 131) minutes. The median duration of anaesthesia in dogs that developed complications was 210 (IQR 150 to 320) minutes, compared to 188 (IQR 134 to 221) minutes in dogs without development of complications. Similarly, the median duration of surgery in dogs with complications was 115 (IQR 101 to 159) minutes, compared to 100 (IQR 61 to 124) minutes for dogs without complication development.

Peri- and postoperative antibiotics were administered in all of the cases. Antibiotics were administered for a median time of 10 days (range 6 to 42 days). Samples for bacterial cultures were taken at the end of surgical exploration in 29 cases and were positive in nine of these cases (31%). Median time from the traumatic event to presentation to the referral institution in cases with positive bacterial cultures was 10 (2 to 336) hours compared to 6 (3 to 168) hours in dogs with negative culture results. The most common pathogen isolated was *Esherichia coli* (n=5), followed by *Staphylococcus species* (n=2), *Bacillus species* (n=2), and single cases of *Enterobacter cloaceae, Enterococcus species* and *Pseudomonas putida.* Samples from two cases cultured more than one bacterial isolate (*E. coli / Bacillus sp.* and *E. coli / Bacillus sp. / Enterococcus sp.*). Seven out of nine (78%) positive bacterial culture results were obtained from wounds caused by wooden objects, in five out of which (71%) the object or fragments of it were present in the wound at surgery. The remaining two cases with positive cultures were deer attack wounds. Four of the positive bacterial cultures at time of surgery were associated with complications (*E. coli* (n=2) – wound healing complications, *E. coli and Bacillus sp.* (n=1) – death, *Enterobacter cloaceae* (n=1) – wound breakdown, abscessation and pneumothorax).

Median hospital stay was five days (range 0 to 25 days). Dogs undergoing thoracotomy alone stayed hospitalised for a median of five days (range 2 to 10 days), similarly to dogs undergoing coeliotomy alone (median 5 days, range 2 to 9 days). Dogs that underwent thoracotomy combined with coeliotomy stayed in hospital longer (median 7.5 days, range 5 to 13 days). The shortest median hospital stay was recorded for dogs undergoing wound exploration alone, with a median of three days (range 0 to 6 days) compared to the overall median of five days.

Complications:

Twenty-three complications occurred in 19 out of 54 dogs (35%) and were classified as minor (n=13) in 13 cases (68%) and major (n=10) in six (32%), in four of which they resulted in death or euthanasia.

One of the 13 minor complications was intraoperative and consisted of supraventricular arrhythmia that resolved after volume resuscitation. Early postoperative complications (<14 days) (n=14) were recorded in 12 dogs (22%) and were considered minor (wound related complications (n=4), drain related complications (n=2), anorexia requiring nasoesophageal tube placement (n=1)) and major (uroabdomen requiring partial cystectomy (n=1), tension pneumothorax requiring second surgery (n=1), wound breakdown and deterioration requiring second surgery (n=1) after which the dog further deteriorated and was subsequently euthanased (n=1), pleural effusion and pneumothorax requiring second surgery (n=1) followed by euthanasia of that dog seven days post second operation (n=1), death (n=1)). Individual complications are detailed in Table 3. Fifty-one dogs (94%) survived until hospital discharge.

Late postoperative complications (14 days – 3 months) (n=8) were recorded in seven dogs (13%) and were considered minor in five and major in three cases. Minor complications consisted of wound dehiscence requiring open wound management (n=2), persistent cough with a bronchointerstitial radiographic lung pattern (n=1), intermittent dyspnoea with seizure-like episodes and supraventricular premature complexes (n=1) and an abscess lesion of the interventricular septum that resolved after four weeks of antibiotic treatment (n=1). Major late postoperative complications were: persistent neurological dysfunction (n=1), lung abscessation requiring lung lobectomy (n=1) and recurrent abscessation of a wound treated by open management after dehiscence prompting euthanasia (n=1).

Four dogs (7%) died or were euthanased as a consequence of their injuries or surgery. One dog suffered cardiorespiratory arrest in the hospital one day after wound exploration and wooden stick removal from a lateral thoracic wall wound previously managed at the referring practice. Post mortem examination revealed fibronecrotic myositis of the dorsal paraxial muscles. *Escherichia coli* was cultured from the wound and spleen consistent with haematogenous dissemination. One dog was euthanased 11 days following initial surgery after sustaining a left axillary injury where a wooden stick penetrated the thoracic wall, diaphragm and stomach. A wound exploration, midline sternotomy and coeliotomy were performed. Additional surgery was required nine days afterwards following breakdown of the sternotomy wound. At repeat surgery a severely thickened pericardium and lung cortications were found. The dog's clinical condition deteriorated two days following revision surgery and he was euthanased. One dog was euthanased 10 days following initial surgery after sustaining an unknown penetrating injury to the right ventral thorax where the object penetrated the thoracic wall and right ventricle of the heart. Three days after wound exploration, midline sternotomy and ventricular repair further surgery was required. This consisted of repeated midline sternotomy, ligation of internal thoracic and intercostal arteries and subtotal pericardectomy. After the second surgery the wound had dehisced, pneumothorax and pleural effusion developed and the dog was euthanased. One dog was discharged two days following surgery to explore a caudal ventral neck wound and tracheal repair after an unknown object penetration. Three months postoperatively the dog was euthanased due to persistent abscessation of an openly managed wound.

When cases were grouped with respect to the type of surgery performed, the highest occurrence of complications resulted from thoracotomy (37%) (n=11, 8 minor, 3 major), followed by wound exploration alone (36%) (n=5, 3 minor, 2 major), coeliotomy (18%) (n=2, 1 minor, 1 major) and dorsal laminectomy (n=1, major). When focusing on dogs which had foreign bodies or their remnants retained in the wound, complications occurred in 40% of associated cases, compared to 32% in dogs where a foreign body was not present in the wound.

Outcome:

Outcome information was available for 49/54 dogs with a median follow-up time of 27 months (range 3 to 145 months), as five dogs were lost to follow up (Dogs No. 5, 15, 18, 21, 27). Survival at 12 months was 90% (44/49 dogs – this accounts for four deaths in the postoperative period (Dogs No. 6, 30, 41, 49), and 1 dog who made full recovery but died of an unknown cause at an unknown time (Dog No. 44)).

Postoperative outcome was excellent (full recovery) in 93% of cases (42/45 dogs – this accounts for four deaths in the postoperative period and five dogs lost to follow up). Dog No. 44 made a full recovery and died of causes unrelated to his injury at an unknown date. Dog No. 36 died 20 months after surgery due to progression of chronic kidney disease. It is unknown if the dog had kidney disease before surgery which may have been exacerbated by general anaesthesia and/or surgery. No. 10 died five years post surgery whilst having a seizure. This dog had a diagnosis of epilepsy and developed occasional dyspnoeic episodes after surgery. Dog No. 13 was receiving ongoing rehabilitation for neurological dysfunction 30 months after surgery.

Discussion

Truncal impalement injuries are challenging cases which may involve injury to multiple organs and body systems and require thorough exploration and multi-disciplinary management. According to our results, excellent outcomes can be achieved with a targeted approach in cases of impalement injuries of dogs. Complications were encountered in 35% of the here presented cases, however 93% achieved excellent outcomes, with a long-term survival rate of 90%.

We report both Type I and Type II injuries. However, in most of our cases the impaling object was not found visibly protruding from the dog at presentation. The authors considered impalement trauma to be a definition of cause of injury, rather than a definition of patient presentation. Based on our data impalement is an uncommon cause of injury, with roughly just over one dog per year surgically treated at each participating referral centre. Affected dogs were commonly of working breeds and were almost exclusively medium and large breeds. Small dogs may not be able to generate enough momentum to cause severe penetrating injury by running onto an object (White & Lane 1988), and assumingly may also be less inclined to behave in such a manner as to suffer impalement.

In previously published reports of penetrating oropharyngeal injuries, the majority of cases (76-82%) presented as chronic cases (more than seven days post injury) (White & Lane 1988; Griffiths *et al.* 2000). This differs from our study population, where only 9% of cases presented more than seven days after the traumatic event, highlighting the different characteristics between these two types of penetrating injuries, indicating a higher severity of trauma, morbidity and perhaps owner awareness of injuries associated with cases of impalement.

Previous reports of non-oropharyngeal impalement injuries are limited to 10 cases of thoracic and/or abdominal penetration (Zitz *et al.* 2007; Pelosi *et al.* 2008; Menard & Schoeffler 2011; Appleby *et al.* 2015). Our report also includes 22% of cases without body cavity penetration. Advanced diagnostic imaging and subsequent thorough wound exploration are required to identify extent of injury, cavitary penetration, injuries to internal organs or presence of foreign material in the wound tract. Therefore, a suspected truncal impalement injury should be assumed to be a penetrating injury until proven otherwise.

The most common entry site of body penetration in this study was the thoracic wall and the pleural cavity was penetrated in more than half of the cases presented, which correlates with the number of thoracotomies performed. Bellenger *et al.* (1996) have previously reported a high survival rate (100%) for thoracotomy associated with thoracic trauma. The conclusion in that study however was based on one thoracic trauma case only (Bellenger *et al.* 1996). Here we present a 93% survival rate for 30 thoracotomies – a more representative finding. This compares favourably to the survival rates for thoracotomy for thoracic bite wounds (82-89%) (Shamir *et al.* 2002; Scheepens *et al.* 2006). The surgical approach for thoracic exploration in this study was dictated by diagnostic imaging findings and surgeon preference. Lung lobectomy was the most frequently performed intrathoracic procedure, being performed in one third of the cases undergoing thoracotomy.

The most common cause of injury was penetration by a wooden object. Wood is at risk of fragmentation and retention of pieces within the wound tract or penetrated body cavity, with the potential for migration, abscessation and draining tract formation (Scalf 2006). This characteristic differentiates wooden objects from the other penetrating objects recorded in this case series. Most of the positive bacterial cultures were from wounds caused by wooden objects and in more than half of these, wood was present in the wound at surgery. Positive cultures were also obtained from deer attack wounds indicating the potentially high nature of contamination of these wounds. Deer attacks and knife stab wounds (Type II impalement) have previously not been reported in the veterinary literature and have also been included in this study, as they by character fit into the category of similar velocity and mass of the object causing the penetration alike stick or metallic object impalements, as opposed to gunshot or bite wound injuries. All but one of the injuries in the "unknown cause" category were presumed wooden stick impalements unwitnessed by the owner. The remaining case was a presumed knife stab.

The impaling object was *in situ* in 26% of dogs at presentation. *In situ* objects penetrating into the wound have previously only been reported in four out of 64 cases of oropharyngeal penetrations in one study (White & Lane 1988). According to reports in human medicine it is essential not to manipulate an impaled object before the patient is stable and prepared for surgery as this minimises blood loss by maintaining tamponade of damaged vascular structures and avoids further traumatic injury as a result of extraction (Kelly *et al.* 1995; Eachempati *et al.* 1999;

Thomson & Knight 2000). Despite the object not being present in the dog in nearly three quarters of the cases, this largely did not influence the prognosis. This may be due to the object not causing severe enough injury (i.e. only subcutaneous penetration, small diameter of object, splintering of object) or rapid veterinary intervention. The object may often also displace internal organs rather than penetrating them (Thomson & Knight 2000). In cases where the object was not found remaining in the penetrating wound, these injuries were classified as impalements according to the history, clinical presentation, diagnostic imaging and surgical findings. A wooden fragment(s) was retrieved in 37% of cases in this study, which is comparable to findings from studies evaluating oropharyngeal injuries where such fragments were retrieved in 34-38% of cases (Griffiths *et al.* 2000; Doran *et al.* 2008).

A variety of imaging modalities were used in this case series, the choice of which was dictated by injury characteristics (clinical presentation, type of object, location and suspicion of injury), clinician preference and costs. Computed tomography has been recommended in cases suspicious of penetrating wooden foreign bodies and has been reported successful in detecting wood in chronic injuries in six dogs (Nicholson *et al.* 2008; Appleby *et al.* 2015). A recent study evaluating sensitivity of diagnostic imaging modalities to identify foreign materials in animal musculoskeletal specimens found difficulties in visualising wood with both digital radiography and CT. Wood, with its low radiopacity is well visualised on ultrasonography and MRI. Ultrasound is of limited value in visualising objects inside air-filled cavities and objects located deeper (>3cm depth) (Panigrahi *et al.* 2015), which would often be the case for impalement injuries. Magnetic resonance imaging has been reported to be useful in diagnosing chronic pharyngeal penetration injuries caused by wooden foreign bodies and surgical planning (Dobromylskyj *et al.* 2008). However, MRI may be inconvenient to use or contraindicated in the acute setting due to long image acquisition times, particularly for thoracic imaging. Computed tomography detected wood in 64% of the cases in this report with one false positive result. The low sensitivity and specificity of diagnostic imaging in our case series clearly indicate the value of direct exploration and visualisation of the wounds after initial patient stabilisation in cases with a history or suspicion of impalement, as previously stated (Zitz *et al.* 2007). Depending on intraoperative findings, conversion from a limited wound exploration to thoracic or abdominal cavity surgery may be indicated. Following the here presented results, the authors recommend to limit the choice of diagnostic imaging for a suspected impalement injury case to performing CT for global screening of the extent of injury and intervention planning, and/or ultrasound for specific evaluation of the nature of soft tissue injury and improved chances of identification of foreign wooden material, depending on impalement location.

Endoscopic wound exploration was performed in two cases. Rigid endoscopy has been described as an effective method for assessment and treatment of oropharyngeal stick injuries in nine dogs (Robinson *et al.* 2014). This may help avoid more invasive surgical wound exploration including thoracotomy or coeliotomy in selected cases, and therefore reduce tissue trauma and recovery times (Robinson *et al.* 2014), or indeed precede more extensive wound exploration where warranted. Rigid endoscopy could be indicated in stable patients as a screening tool to identify the extent of injury, especially that of solid organs. Advanced procedures and user experience could be factors limiting the use and usefulness of this modality. Future comparison of endoscopic and maximally invasive penetrating tract exploration for truncal injuries is required before specific recommendations can be made.

Limitations of this study relate largely to its retrospective nature, including the reliance on accurate historical data recording, as well as the involvement of multiple clinicians at a number of different referral institutions. There was wide variability between individual cases making grouping difficult. Also, the population of dogs was likely skewed as the worst affected may not have survived to the point of referral to a specialist institution. Similarly some minor impalement injuries may have been managed by first opinion practices.

In conclusion, despite the often dramatic presentation of dogs suffering impalement injuries the majority of patients which are stable enough for transport to a referral centre for specialist care can achieve successful outcomes. Impalement injuries require thorough diagnostic imaging and interpretation prior to thorough surgical exploration and management, augmented by anaesthetic and critical care during the peri- and post-operative periods.

Conflict of interest:

No conflicts of interest have been declared.

References

Appleby, R., zur Linden, A., Singh, A., et al., 2015. Computed tomography diagnosis of a thoracic and abdominal penetrating foreign body in a dog. *The Canadian Veterinary Journal*, 56(11), pp.1149–1152.

Bellenger, C.R., Hunt, G.B. & Goldsmid, S.E., 1996. Outcomes of thoracic surgery in dogs and cats. *Australian Veterinary Journal*, 74(1), pp.25-30.

Cabon, Q., Deroy, C., Ferrand, F.-X., et al., 2015. Thoracic bite trauma in dogs and cats: a retrospective study of 65 cases. *Veterinary and Comparative Orthopaedics and Traumatology*, 28(6), pp.448–454.

Dobromylskyj, M.J., Dennis, R., Ladlow, J.F., et al., 2008. The use of magnetic resonance imaging in the management of pharyngeal penetration injuries in dogs. *Journal of Small Animal Practice*, 49(2), pp.74–79.

Doran, I.P., Wright, C.A. & Moore, A.H., 2008. Acute oropharyngeal and esophageal stick injury in forty-one dogs. *Veterinary Surgery*, 37(8), pp.781–785.

Eachempati, S.R., Barie, P.S. & Reed, R.L., 1999. Survival after transabdominal impalement from a construction injury: a review of the management of impalement injuries. *The Journal of Trauma*, 47(5), pp.864–866.

Griffiths, L.G., Tiruneh, R. & Sullivan, M., 2000. Oropharyngeal penetrating injuries in 50 dogs: a retrospective study. *Veterinary Surgery*, 29(5), pp.383–388.

Kelly, I.P., Attwood, S.E.A., Quilan, W., et al., 1995. The management of impalement injury. *Injury*, 26(3), pp.191–193.

Menard, J. & Schoeffler, G.L., 2011. Colonic, ureteral, and vascular injuries secondary to stick impalement in a dog. *Journal of Veterinary Emergency and Critical Care*, 21(4), pp.387–394.

Morgan, T., Butler, S. & Schwab C.W., 1988. Impalement injury: case study and management guidelines. *Critical Care Nurse*, 8, pp.82-85.

Nicholson, I., Halfacree, Z., Whatmough, C., et al., 2008. Computed tomography as an aid to management of chronic oropharyngeal stick injury in the dog. *Journal of Small Animal Practice*, 49(9), pp.451–457.

Oxford English dictionary (2017) *Impale.* [Online] Oxford University Press. Available from: https://en.oxforddictionaries.com/definition/impale [accessed May 4 2017].

Panigrahi, R., Dash, S.K., Palo, N., et al., 2015. Foreign Body Detection in Musculoskeletal Injuries: A In Vitro Blinded Study Comparing sensitivity among Digital radiography, Ultrasonography, CT and Magnetic Resonance Imaging. *Musculoskeletal Regeneration*, 2: e649.

Pavletic, M.M., 2011. Management of specific injuries, Impalement injuries. In: Atlas of small animal wound management and reconstructive surgery, 3rd edn. W. B. Saunders, Philadelphia. p.214.

Pelosi, A., Hauptman, J.G. & Eyster, G.E., 2008. Myocardial perforation by a stick foreign body in a dog. *Journal of Veterinary Emergency and Critial Care*, 18(2), pp.184–187.

Risselada, M., de Rooster, H., Taeymans, O., et al., 2008. Penetrating injuries in dogs and cats. *Veterinary and Comparative Orthopaedics and Traumatology*, 21(5), pp.1–6.

Robinson, W., Shales, C. & White, R.N., 2014. The use of rigid endoscopy in the management of acute oropharyngeal stick injuries. *Journal of Small Animal Practice*, 55(12), pp.609–614.

Scheepens, E.T.F., Peeters, M.E., L'Eplattenier, H.F., et al., 2006. Thoracic bite trauma in dogs: a comparison of clinical and radiological parameters with surgical results. *Journal of Small Animal Practice*, 47(12), pp.721–726.

Shamir, M.H., Leisner, S., Klement, E., et al., 2002. Dog bite wounds in dogs and cats: a retrospective study of 196 cases. *Journal of Veterinary Medicine,* 49(2), pp.107–112.

Thomson, B.N. & Knight, S.R., 2000. Bilateral thoracoabdominal impalement: avoiding pitfalls in the management of impalement injuries. *The Journal of Trauma*, 49(6), pp.1135–1137.

White, R.A.S. & Lane, J.G., 1988. Pharyngeal stick penetration injuries in the dog. *Journal of Small Animal Practice*, 29(1), pp.13–35.

Zitz, J., Rozanski, E.A., Berg, J., et al., 2007. *Managing dogs with thoracic impalement injuries: A review of nine cases*. [Online]. Available from: http://veterinarymedicine.dvm360.com/managing-dogs-with-thoracic-impalement-injuries-review-nine-cases?id=&pageID=1&sk=&date= [accessed August 25 2016].

Table 1. Cases treated for impalement injuries grouped by impalement site. § wound exploration was in one case done endoscopically, one case had both left and right thoracic wall penetrations, [1] additional diaphragmatic myotomy was performed in one case for abdominal exploration.

Entry Point	Number of cases	Single modality imaging			Multimodality imaging				Penetrated body cavity				Surgery Performed		
		RAD	CT	US	RAD/US	RAD/CT	RAD/US/CT	CT/MRI	Thoracic	Abdominal	Both	None	Wound exploration	Thoracotomy	Coeliotomy
Axilla	10	3	2			3	1		7		2	1	10	5MS, 2ICT	2
Lateral thorax	12	7	1			3			8		3	1	12	3MS, 6ICT	2
Ventral thorax	14	7	4		1	1	1		11		1	2	14	6MS, 3ICT	1
Thoracic inlet	8	2	2		1	1	1	1	4			4	8	3MS, 1ICT	
Caudal neck	1											1	1		
Cranial to shoulder	1	1										1	1		
Inguinal area	6	1	1	1	2		1			5		1	3		5
Inguinal area and lateral thoracic wall	2	1			1						1	1	2	1MS	1
Total	54	38	23	10					37	12		12	51	18 MS, 12 ICT	11

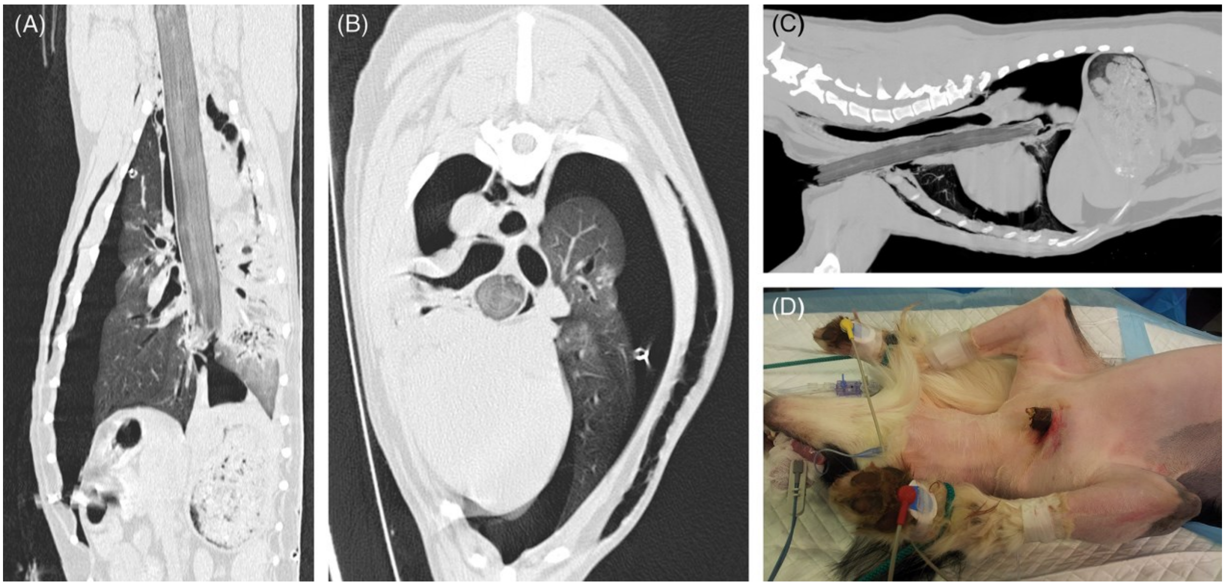
Legend for Table 1. ICT – intercostal thoracotomy, CT – computed tomography, MRI – magnetic resonance imaging, MS – median sternotomy, RAD – radiography, US – ultrasound

Table 2. Cases treated for impalement injuries that underwent thoracotomy.

	Median sternotomy	Intercostal thoracotomy	Total
Total number	18	12	30
Complications	33%	42%	37%
Lung lobectomy	28%	42%	33%
Mean surgery time in minutes (interquartile range)	125,5 (101 to 131)	127,5 (85 to 174)	126 (100 to 135)
Median surgery time in minutes (range)	115 (70 to 280)	115 (65 to 225)	115 (65 to 280)
Median hospital stay in days (range)	5 (2–13)	5 (2 to 9)	5 (2 to 13)
Additional coeliotomy	4	2	6
Additional diaphragmatic myotomy	–	1	1
Survival	89%	100%	93%

Figure headings:

Figure 1: Dorsal (A), transverse (B) and 3D curved multiplanar (C) reconstruction images of computed tomography data of dog No. 25. A wooden stick is entering the axilla and can be traced into the thorax. Photograph of the same dog in dorsal recumbency being prepared for surgery (D). Wound exploration and median sternotomy were performed to retrieve the wooden stick. No internal organs were injured; outcome was excellent.



Flow chart: Flow chart navigating through cases from presentation to surgery. Dashed lines signify that not all dogs from the respective group went on to have the indicated procedure.